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Prediction of the Value of Ancient Buildings Based on Building Conservation Cost Modeling

Yue Tang*

School of Economic Management and Law, University of South China, Hengyang, 421001, China
**Corresponding author: yuetang6688@163.com*

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Abstract: Persistent heat, heavy rainfall, intense thunderstorms. Frequent extreme weather events have made the preservation of ancient buildings increasingly difficult. Therefore, this paper explores the preservation and value of ancient buildings, which is useful in helping insurance companies and property owners make decisions. First, in order to quantitatively analyze how much measures community leaders should take to protect buildings in their communities, this paper defines the maximum degree of measures as the cost of protection of the building, and assigns weights to the three indicators of human, material, and financial resources using the entropy weighting method and the coefficient of variation method. Secondly, the cost rate is multiplied by the gross product of the region, which is the maximum cost spent on the protection of the building. Finally, this paper chooses Dunhuang Mogao Grottoes as a historical landmark and uses the building cost protection model to evaluate the value of this historical landmark, and the results show that Dunhuang Mogao Grottoes is valued at about 3.393 billion yuan.

1. Introduction

As severe climate change has exacerbated the occurrence of extreme weather and natural disasters, leading to increasing threats to ancient buildings, while the coverage between the economic losses caused by natural disasters and the amount of insured losses of ancient buildings has gradually widened, which makes it necessary for insurance companies to rethink the location and underwriting methods [1]. In the face of the comprehensive consideration of many factors, involving costs, social, economic, natural environment, benefits and other factors, need to be carefully weighed. In order to ensure the sustainable development of insurance for ancient buildings, there is an urgent need to establish a modeling method for calculating the value of ancient buildings in order to better protect them [2].

On the issue of cost of ancient building protection, it involves the scale of restoration project, technical difficulty, material cost, labor cost, time cost and other aspects of the complex factors. Therefore, to accurately calculate the cost of ancient building protection, it is usually necessary to combine the actual situation of a specific project to carry out a detailed analysis and assessment. In the Chinese region, the insurance amount of ancient buildings is usually based on the valuation of the insured, with reference to the highest maintenance costs assessed by authoritative government departments [3]. Wei Yong scholars analyzed the target management of ancient building protection project, based on the target management method, in-depth study of the cost of ancient building protection project [4]. In addition, some scholars measured and quantitatively assessed the value of ancient buildings through field surveys and using different methods, such as conditional value method, fuzzy comprehensive evaluation method and hierarchical analysis method [5-8].

Among the many landmarks that have experienced extreme weather, this paper chooses to take the Mogao Caves in Dunhuang as an example for in-depth study. Located in Gansu Province, China, the Mogao Caves of Dunhuang are situated in an arid region in the northwest of China, where the main landforms are deserts and sand dunes, and their harsh geographical and climatic conditions make them vulnerable to extreme weather and natural disasters. In order to protect this precious cultural heritage, local leaders have invested a lot of human, financial and material resources and adopted various conservation models. Based on the building conservation cost model, this paper will predict the conservation cost of Dunhuang Mogao Grottoes and further analyze the value of ancient buildings. This study is not only important for the protection of Dunhuang Mogao Grottoes, but also provides practical experience and reference for the future development of ancient building insurance.

2. Predictions based on building conservation cost modeling

2.1 Identification of secondary indicators

In order to quantify the primary indicators, after a literature review, this paper finally selected the region's young adult population ratio, energy consumption ratio, and construction industry expenditure ratio as the secondary indicators. As the main labor force, the young and strong population is the main group of people who maintain community buildings; the energy consumption ratio refers to the proportion of energy consumed by a region for daily life or for maintaining buildings after suffering from extreme weather damage; and the construction industry expenditure ratio refers to the proportion of the expenses that a region needs to spend on maintaining buildings after suffering from extreme weather damage on a daily basis [9-10].

2.2 The determination of insurance rates

Insurance premium rate, which is the proportion of premiums charged by the insurer to the policyholder or the insured according to the insurance amount, is divided into pure insurance rate and additional insurance rate. Since the decision of insurance premium rate within a region is determined internally by insurance organizations, it is difficult to standardize the data and the final data obtained varies greatly, therefore, this paper decides to adopt a uniform insurance premium rate after reviewing relevant information, i.e., the insurance premium rate in different regions of Gansu Province are all 0.3 [11].

2.3 The determination of insurance rates

The insurance payout ratio is the ratio between the amount actually paid out by the insurance company to the insured and the premiums paid by the insured over a certain period of time. As the property insurance payout is a complex issue, it involves more uncertain factors, such as the current number of claims, the amount of outstanding claims, etc. Therefore, after reviewing the relevant literature reports, this paper decides to set the range of property insurance payout ratio in Gansu Province as 10%-20%[12].

2.4 Building Conservation Cost Calculations

The calculation steps are as follows:

In the first step, the weights of human, material, and financial resources were calculated by entropy weighting and coefficient of variation methods.

1) Entropy weight method

First of all, since the two secondary indicators in the natural environment are extremely small, they need to be converted into extremely large indicators through forward processing:

$$f(x) = x_{\max} - x_{ij} \tag{1}$$

Where x_{ij} is any data in the indicator and $x_{\max}$ is the maximum in the column where the data resides.

To eliminate the impact of dimensions on the results, the data is also standardized:

$$z_{ij} = x_{ij} \div \sqrt{\sum_{i=1}^{n} x_{ij}} \tag{2}$$

Where z_{ij} is the standardized variable, x_{ij} is a positive matrix.

Then information entropy of each index is defined by:

$$e_j = -\frac{1}{\ln n} \sum_{i=1}^{n} p_{ij} \ln(p_{ij}) \tag{3}$$

Where e_j is the information entropy of the JTH index in the second-level index, p_{ij} is the probability of the data in the *i-th*. It indicates the total number of data.

Then, the utility value of each indicator is calculated and normalized to obtain the weight.

$$d_j = 1 - e_j$$
$$W_1 = \frac{d_j}{\sum_{j=1}^{m} d_j} \tag{4}$$

where d_j is the information utility value of the *j-th*, W_1 is the weight calculated by the entropy weight method, m is the number of indicators.

2) Coefficient of variation method

First, the mean and standard deviation of the secondary index are calculated using the data that has been positively and normalized:

$$\begin{cases} \bar{x}_j = \dfrac{1}{n} \sum_{i=1}^{n} x_{ij} \\ S_j = \sqrt{\dfrac{\sum_{i=1}^{n} (x_{ij} - \bar{x}_j)^2}{n-1}} \end{cases} \tag{5}$$

Where $\bar{x}_j$ is the mean of the JTH indicator, S_j is the standard deviation of the JTH index.

In turn, calculate the coefficient of variation of *j-th* V_j:

$$V_j = S_j \div \bar{x}_j \tag{6}$$

Finally, the weights of all indexes are obtained after the variation coefficients of each index is normalized:

$$w_2 = \frac{CV_j}{\sum_n CV_j} \tag{7}$$

3) Combined weights

With the help of the above two methods, we can obtain the weights of two different indicators. In order to reduce the error and make the model more accurate, we choose the average value of two weights as the final weight of each indicator.

$$w_j = \frac{w_1 + w_2}{2} \tag{8}$$

The second step is to calculate the building conservation cost rate CR_{iy}.

- Covered Areas:

$$CR_{iy} = (w_{HR} HR_{iy} + w_{MR} MR_{iy} + w_{FR} FR_{iy}) \times (IFR - OD_n) \tag{9}$$

- Not Covered Areas:

$$CR_{iy} = w_{HR} HR_{iy} + w_{MR} MR_{iy} + w_{FR} FR_{iy} \tag{10}$$

Among them, HR_{iy} represents the manpower of region *i* in year *y*. MR_{iy} represents the material resources of area *i* in year *y*. FR_{iy} represents the financial strength of region *i* in year *y*.

In the third step, the cost of preserving a building is calculated by multiplying the building preservation cost rate with the gross product of the area. This calculation provides the preservation cost of the buildings in the area for one year:

$$L_{iy} = CR_{iy} \times GP_{iy} \tag{11}$$

Where L_{iy} indicates the costs that should be taken to protect buildings in the community, and GP_{iy} indicates the gross product for the year.

3. Application and analysis

3.1 Valuation of Historic Landmarks

After checking relevant information, this paper finds that the conservation cost of a historical landmark can indirectly assess its value. Therefore, this paper decides to evaluate the value of the landmark by using the building conservation cost model.

3.1.1 Weighting of secondary indicators

In order to assess the conservation cost of Dunhuang Mogao Grottoes in 2023, first of all, this paper uses the ratio of young adult population, the ratio of energy consumption, and the ratio of expenditure on construction industry in Gansu Province in 2013-2022 to calculate the weights of each level of indicators. The final weighting results were obtained as shown in Figure 1: human resources (0.4058), material resources (0.2344), and financial resources (0.3598).

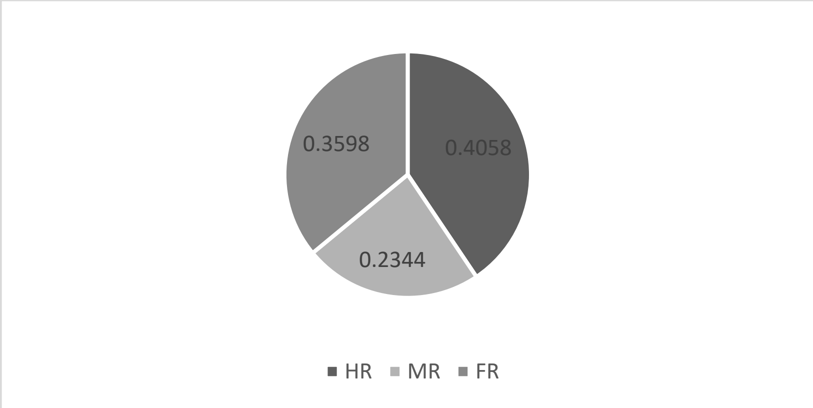

Figure 1: Indicator weighting results

3.1.2 Results of protection cost projections

Then, GM(1,1) was used to predict the data for Gansu Province in 2023, as shown in Figures 2 and 3: human (0.299), material (0.131), financial (0.385), and gross product (11.7 trillion yuan). Finally, the cost rate of the Dunhuang Mogao Grottoes was calculated to be 0.0029 using the building conservation cost model, and the cost was 3.393 billion yuan, thus the value of the Dunhuang Mogao Grottoes was approximately 3.393 billion yuan.

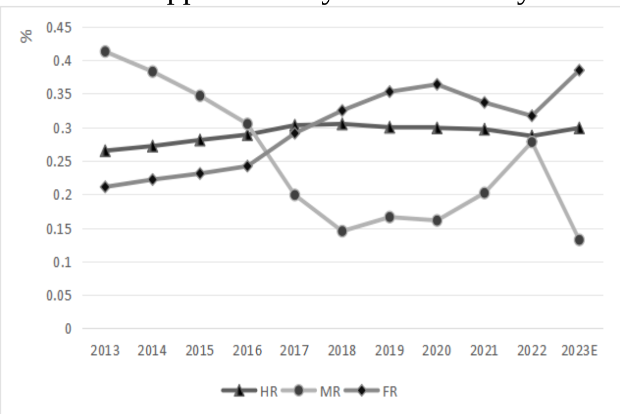

Figure 2: Predicted value of HR,MR,FR

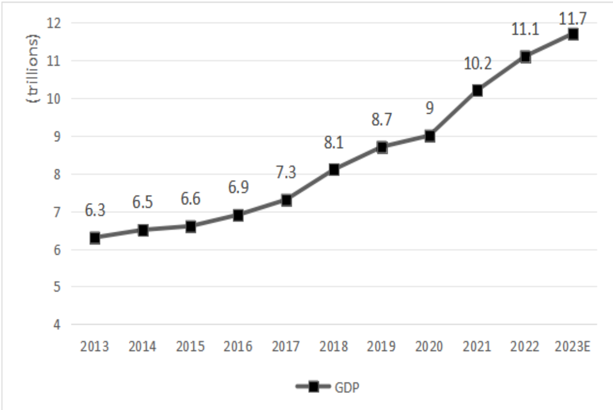

Figure 3: Forecast of GDP of Gansu Province

4. Conclusions

In summary, this paper predicts the value of the Dunhuang Mogao Grottoes to be about 3.393 billion dollars using the building protection cost model. The model is simple and convenient in application, easy to operate and understand. But the factors considered by the model are not comprehensive enough and the indicators are selected less. Therefore, it may lead to some errors in the prediction results. Nevertheless, the prediction results in this paper still have certain reference value. As a world cultural heritage, the historical, artistic and scientific value of Dunhuang Mogao

Grottoes is immeasurable. The prediction results of this paper can provide certain reference for relevant departments to better protect and utilize this valuable resource. In order to further improve the accuracy of the prediction results, this paper can further improve the building protection cost model and add more influencing factors and indicators. At the same time, other methods can also be considered for prediction and assessment, such as market comparison method and income method. Through the comprehensive application of multiple methods, this paper can understand the value of Dunhuang Mogao Grottoes more comprehensively and provide a more scientific basis for the protection and utilization of this world cultural heritage.

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